Distant Titan Scatterometry/Radiometry in S10, Rev 6

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- Sequence: s10

- Rev: 006

- Observation Id: ti_006_1

- Target Body: Titan

1 Introduction

This memo describes one of the Cassini RADAR activities for the s10 sequence of the Saturn Tour. A sequence design memo provides the science context of the scheduled observations, an overview of the pointing design, and guidlines for preparing the RADAR IEB.

2 CIMS and Division Summary

Each RADAR observation is represented to the project by a set of requests in the Cassini Information Management System (CIMS). The CIMS database contains requests for pointing control, time, and data volume. The CIMS requests show a high-level view of the sequence design. Table 1 shows the CIMS request summary for this observation.

The CIMS requests form the basis of a pointing design built using the project pointing design tool (PDT). The details of the pointing design are shown by the PDT plots on the corresponding tour sequence web page. (See https://cassini.jpl.nasa.gov/radar.) The RADAR pointing sequence is ultimately combined with pointing sequences from other instruments to make a large merged c-kernel. C-kernels are files containing spacecraft attitude data.

A RADAR tool called RADAR Mapping and Sequencing Software (RMSS) reads the merged c-kernel along with other navigation data files, and uses these data to produce a set of instructions for the RADAR observation. The RADAR instructions are called an Instrument Execution Block (IEB). The IEB is produced by running RMSS with a radar config file that controls the process of generating IEB instructions for different segments of time. These segments of time are called divisions with a particular behavior defined by a set of division keywords in the config file. Table 2 shows a summary of the divisions used in this observation. Subsequent sections will show and discuss the keyword selections made for each division. Each division table shows a set of nominal parameters that are determined by the operating mode (eg., distant scatterometry, SAR low-res inbound). The actual division parameters from the config file are also shown, and any meaningful mismatches are flagged.

3 Warmup

The radar warmup rider begins at 2005-04-17T22:25:00.000 (-03:00:0.0) and lasts for the standard 03:00:0.0. During the warmup, the IEB will be set for slow speed radiometer only data as shown in table 4.

CIMS ID	Start	End	Duration	Comments
006OT_WARM4RCAL001_RIDER	2005-107T22:25:00	2005-108T01:25:00	03:00:0.0	Warmup for calibration and science data collection.
006TI_SOUTHSCAT001_PRIME	2005-108T01:25:00	2005-108T02:25:00	01:00:0.0	Scatterometry of Titan. Range dependent request. Needs to be as close as possible to the segment boundary since this is shorter range.
006TI_SOUTH5CAL001_PRIME	2005-108T02:25:00	2005-108T03:25:00	01:00:0.0	Obtain distant Titan radiometer science and calibration data. One of a set that provides coverage of Titan southern latitude variation along with some obtainable associated longitude variation.
006OT_SRCRADCAL001_PRIME	2005-108T03:25:00	2005-108T10:25:00	07:00:0.0	Scan the Saturn, and microwave sources while collecting radiometry data.

Table 1: ti_006_1 CIMS Request Sequence

4 Div's B,D,E: Radiometry

Figure 1 shows the pointing design for the radiometry scan from the merged ckernel. The scans use 1/4 beamwidth spacing to allow for some super-resolution processing of the radiometer data. The angular size of the target is about 7.7 mrad during this division. The beam 3 beamwidth is 6 mrad. The IEB for this division and the other radiometry divisions is controlled by a block of keywords as shown in Table 5

Division D sets aside time for a set of radiometer integration period tests during the final part of the target staring time. These tests are manually inserted using the user edit capabilities of RMSS. They vary the radiometer, and two internal reference load integration periods so that time and count offsets can be computed for proper normalization.

Division	Name	Start	Duration	Data Vol	Comments
a	distant_warmup	-3:20:0.0	03:20:0.0	3.0	Warmup
b	distant_radiometer	00:00:0.0	00:24:0.0	1.4	Radiometer before scatt
c	distant_scatterometer	00:24:0.0	00:20:24.0	259.5	Scatterometer stare
d	distant_radiometer	00:44:24.0	00:03:0.0	0.2	Radiometer integration period tests
e	distant_radiometer	00:47:24.0	01:42:36.0	6.1	Radiometer scans
Total				270.2	

Table 2: Division summary. Data volumes (Mbits) are estimated from maximum data rate and division duration.

Div	Alt (km)	Slant range (km)	B3 Size (target dia)	B3 Dop. Spread (Hz)
a	556761	off target	0.70	off target
b	628644	off target	0.79	off target
c	637312	637312	0.80	1031
d	644687	644687	0.81	1041
e	645772	645772	0.81	1042

Table 3: Division geometry summary. Values are computed at the start of each division. B3 Doppler spread is for two-way 3-dB pattern. B3 size is the one-way 3-dB beamwidth

Name	Nominal	Actual	Mismatch	Comments
mode	radiometer	radiometer	no	
start_time (min)	varies	-200.0	no	
end_time (min)	varies	0.0	no	
time_step (s)	varies	1800.0	no	Used by radiometer only modes - saves commands
bem	00100	00100	no	
baq	don't care	5	no	
csr	6	6	no	6 - Radiometer Only Mode
noise_bit_setting	don't care	4.0	no	
dutycycle	don't care	0.38	no	
prf (KHz)	don't care	1.00	no	
number_of_pulses	don't care	8	no	
n_bursts_in_flight	don't care	1	no	
percent_of_BW	don't care	100.0	no	
auto_rad	on	on	no	
rip (ms)	34.0	34.0	no	
max_data_rate	0.250	0.248	yes	Kbps - set for slowest burst period
interleave_flag	off	off	no	
interleave_duration (min)	don't care	10.0	no	

Table 4: ti_006_1 div_a distant_warmup block

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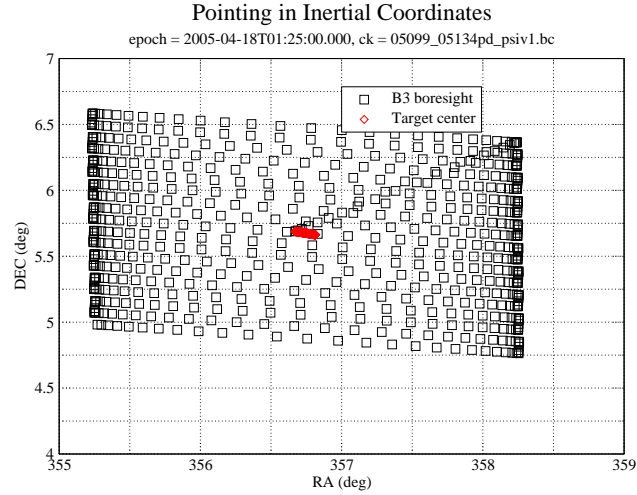
Figure 1: Outbound scan in inertial coordinates

| Name	Nominal	b	d	e	Mismatch	Comments
mode	radiometer	radiometer	radiometer	radiometer	no	
start_time (min)	varies	0.0	44.4	47.4	no	
end_time (min)	varies	24.0	47.4	150.0	no	
time_step (s)	varies	600.0	1800.0	1800.0	no	Used by radiometer only modes
bem	00100	00100	00100	00100	no	
baq	don't care	5	5	5	no	
csr	6	6	6	6	no	
noise_bit_setting	don't care	4.0	4.0	4.0	no	
dutycycle	don't care	0.38	0.38	0.38	no	
prf (KHz)	don't care	1.00	1.00	1.00	no	
number_of_pulses	don't care	8	8	8	no	
n_bursts_in_flight	don't care	1	1	1	no	
percent_of_BW	don't care	100.0	100.0	100.0	no	
auto_rad	on	on	off	on	yes	
rip (ms)	34.0	34.0	34.0	34.0	no	starting value for auto-rad
max_data_rate	1.000	0.992	0.992	0.992	yes	1 Kbps - 1 s burst period which is adequate for slow radiometer scans
interleave_flag	off	off	off	off	no	
interleave_duration (min)	don't care	10.0	10.0	10.0	no	

Table 5: ti_006_1 div_bde distant_radiometer block
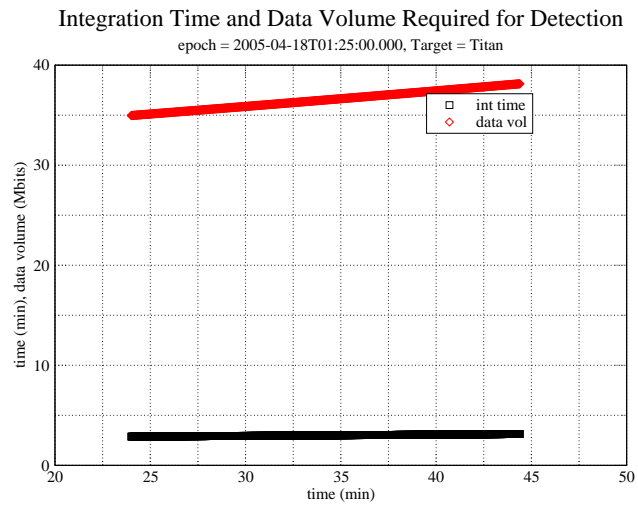
Figure 2: Outbound scatterometry Div C: Detection integration time required for a single point detection using optimal chirp bandwidth
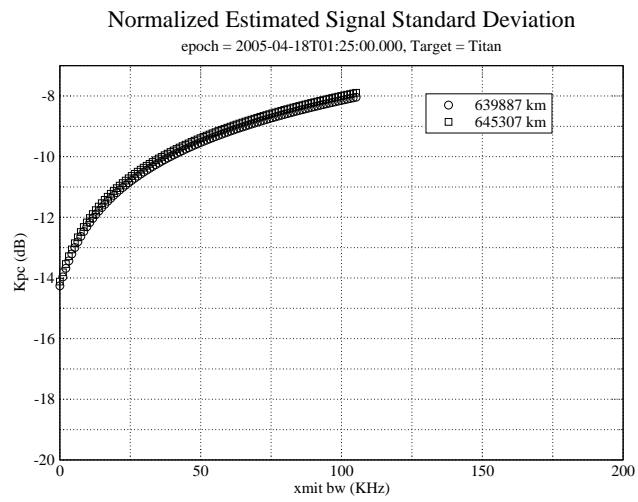

Figure 3: Outbound observation Div C: Normalized estimated signal standard deviation for a disk integrated observation assuming all the bursts occur at minimum range, and 15 minutes away from minimum range.

Name	Nominal	Actual	Mismatch	Comments
mode	scatterometer	scatterometer	no	
start_time (min)	varies	24.0	no	
end_time (min)	varies	44.4	no	
time_step (s)	don't care	15.0	no	Used when BIF > 1, otherwise set by valid time calculation
bem	00100	00100	no	
baq	5	5	no	
csr	0	0	no	0 - Normal Operation, 8 - with auto-gain
noise_bit_setting	4.0	4.0	no	Scat signal set higher than ALT/SAR
dutycycle	0.70	0.60	yes	
prf (KHz)	varies	1.95	no	Set to cover target doppler bandwidth
number_of_pulses	varies	135	no	depends on PRF choice (can have more shorter pulses)
n_bursts_in_flight	varies	7	no	Used to increase PRF and data rate at long range
percent_of_BW	0.0	0.0	no	
auto_rad	on	on	no	
rip (ms)	34.0	34.0	no	
max_data_rate	200.000	212.000	yes	Kbps - determines burst period
interleave_flag	off	off	no	
interleave_duration (min)	don't care	10.0	no	

Table 6: ti_006_1 div_c distant_scatterometer block

5   Div C: Scatterometer Performance

During the scatterometer integration the spacecraft will have beam 3 pointed at the center of Titan. The detection performance is shown in figures 2 and 3. Division parameters are as shown in table 6.

A tone transmission will be used because the signal is too weak to allow for any range compression processing. The PRF will be set higher than the disk bandwidth to allow for doppler processing without any folding of the signal onto itself from the comb pattern generated by the pulsed nature of the signal. The resolution of the signal as a function of doppler will be limited due to the weak signal. This is not a big issue for this observation because its primary purpose is to provide a disk integrated backscatter value for calibration against Earth based radar measurements of Titan. Any doppler spectrum data will be an extra bonus. This observation will also include an upgraded RMSS calculation that will make the chirp start frequency an integer multiple of the PRF. This is done to keep the echo peak from being split in the frequency domain by the comb pattern due to the pulsed nature of the signal.

The range is large enough that multiple bursts in flight will be needed. Figure 4 shows the receive window delay (RWD) that will be needed for the current pulse parameters shown in table 6. The range of burst periods that are compatible with the number of bursts in flight (giving RWD $\in [0, 1023]$) is also shown. RMSS actually imposes
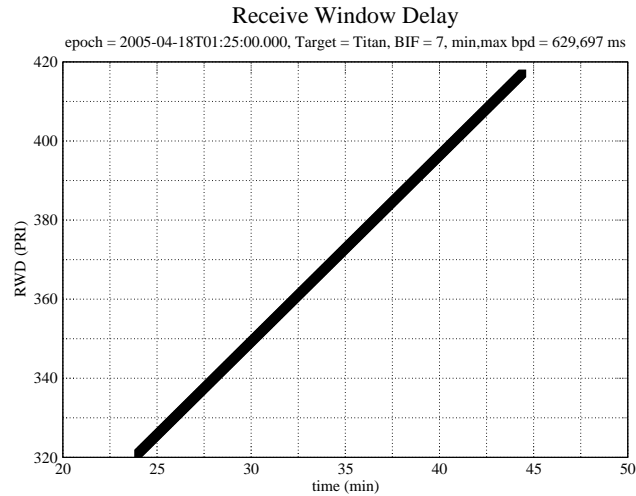
Figure 4: Div C: Outbound scatterometer receive window delay. Subtitle shows the minimum and maximum burst periods that are in principle compatible with the division selected number of bursts in flight.

a more strict limit on RWD to accomodate timing constraints in the instrument. Although not shown in table 6, scatterometer mode operations use a transmit-receive window offset (TRO) of 6 which makes the echo window 6 PRI's longer than the number of pulses transmitted. This is done to increase the valid time for an instruction by letting the pulse echos walk through the longer echo window before the range-gate needs to be updated. The positive TRO value also guarantees noise-only data in each burst which eliminates the need to insert special noise-only bursts.

6 Revision History

1. Apr 05, 2005: Initial release

7 Acronym List

AL	Acronym List
ALT	Altimeter - one of the radar operating modes
BAQ	Block Adaptive Quantizer
CIMS	Cassini Information Management System - a database of observations
Ckernel	NAIF kernel file containing attitude data
DLAP	Desired Look Angle Profile - spacecraft pointing profile designed for optimal SAR performance
ESS	Energy Storage System - capacitor bank used by RADAR to store transmit energy
IEB	Instrument Execution Block - instructions for the instrument
ISS	Imaging Science Subsystem
IVD	Inertial Vector Description - attitude vector data
IVP	Inertial Vector Propagator - spacecraft software, part of attitude control system
INMS	Inertial Neutral Mass Spectrometer - one of the instruments
NAIF	Navigation and Ancillary Information Facility
ORS	Optical Remote Sensing instruments
PDT	Pointing Design Tool
PRI	Pulse Repetition Interval
PRF	Pulse Repetition Frequency
RMSS	Radar Mapping Sequencing Software - produces radar IEB's
SAR	Synthetic Aperture Radar - radar imaging mode
SNR	Signal to Noise Ratio
SOP	Science Operations Plan - detailed sequence design
SOPUD	Science Operations Plan Update - phase of sequencing when SOP is updated prior to actual sequencing
SSG	SubSequence Generation - spacecraft/instrument commands are produced
SPICE	Spacecraft, Instrument, C-kernel handling software - supplied by NAIF to use NAIF kernel files.
TRO	Transmit Receive Offset - round trip delay time in units of PRI